DIVERSITY AS A MANAGEMENT STRATEGY

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The Great Plains' agricultural community is seeking to preserve and enhance the long-term health of its natural resources. Many producers are exploring new agronomic practices that lead to soil sustainability -- renewing or improving the soil's quality.

A key component of sustainability is biodiversity (5). The greater the diversity in plant species, the greater the stability of that ecosystem, whether from an agricultural or native community perspective (15). Diversity leads towards a natural balance within an ecosystem.

WHY DIVERSIFY?

Historical basis:

Agriculture producers have minimized crop diversity. This strategy allows producers to specialize with one or two crops, with the goal of increasing production and profits. However, lack of crop diversity can lead to drastic consequences. For example, in the early 1970s, corn leaf blight (Helminthosporum maydis) severely reduced corn yields in the Corn Belt. This disease infested the entire region because all corn hybrids had similar genetic germplasm that predisposed them to the disease (1, 4).

A similar situation exists today with lack of genetic diversity in northeastern Colorado. In 1995, winter wheat comprised 91% of dryland crops planted in this area (2). Of the wheat acreage, 63% was planted to one variety, Tam 107. A disease outbreak, such as leaf rust, could easily infect this variety throughout the entire region and severely reduce grain yields.

Conceptual basis:

Increased understanding of biological processes stimulates thinking in a cyclic or systems perspective, compared to linear thinking, where cultural decisions are considered only within the

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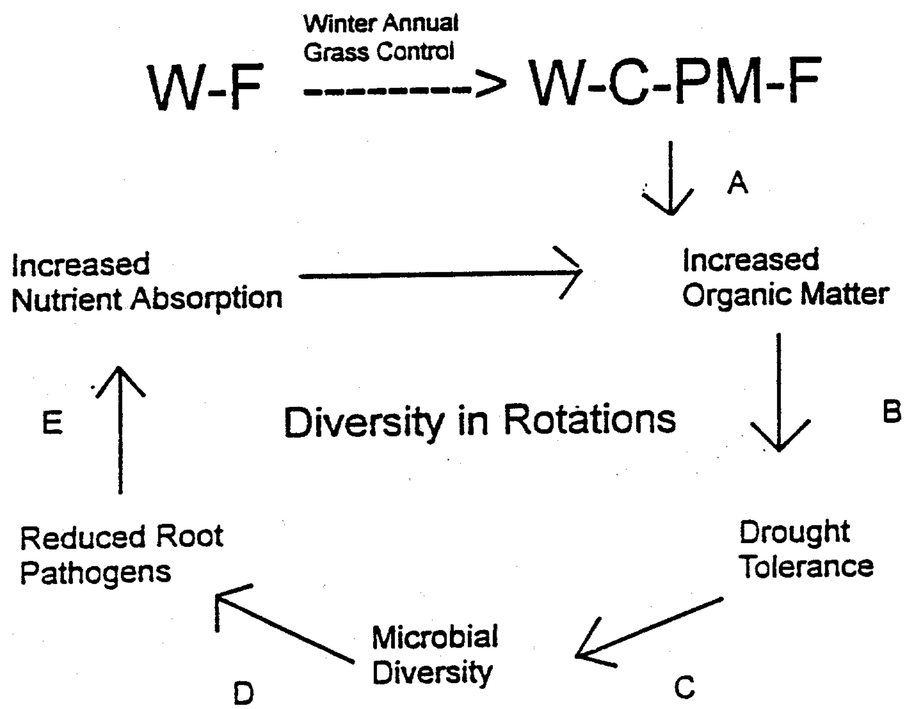
perspective of one growing season (11). Within an ecosystem, natural biological processes interact in a cyclic manner, and crop diversity enhances the favorable aspects of this natural cycling (4, 16). For example, producers in this region are changing their crop rotation to aid in managing winter annual grasses in winter wheat. This strategy allows for the natural decline in the number of weed seeds in the soil, thus leading to less weeds in future wheat crops (3). However, this change in cropping patterns also fosters a favorable biological cycle in the soil (Figure 1).

Figure 1. Effect of diversifying a wheat-fallow rotation on biological processes in soil. Letters on the graph correspond to designated paragraphs in the following text.



Changing the rotation from wheat-fallow to wheat-corn-proso millet-fallow leads to:

A. Increased organic matter:

By changing to a more intensive rotation such as winter wheat-corn-proso millet-fallow, organic matter in the soil's top two inches is increased 20% compared to wheat-fallow, after only six years of cropping (6).

B. Drought tolerance:

The increase in soil organic matter improves precipitation infiltration into the soil, while reducing soil water evaporation due to larger surface soil aggregation (4). The combination of these factors decreases the effect of drought stress on crop yield (19, 20).

C. Microbial diversity:

Microorganisms specific to a crop increase in population during the growing season (13). By diversifying crops in the rotation, the soil microflora also is diversified (12), leading to microbial population stability in the soil (13).

D. Reduced root pathogens:

Soils with a diversity of microorganisms exhibit a native antagonism to soil-borne diseases of crops, reducing the level of disease infestation (7, 14). Conversely, continuous planting of the same crop leads to a buildup of soil-borne pathogens associated with that crop (10). Thus, diversity in crop rotation leads to crop plants with healthier roots (7, 13).

E. Increased water and nutrient absorption:

Plants with healthier roots are able to explore a greater volume of soil and subsequently absorb more nutrients and water from the soil profile (7, 24). Furthermore, healthier roots are more efficient in absorbing nutrients from the soil (14, 18). Therefore, efficiency of fertilizer use by crops is improved in diversified rotations (19, 21).

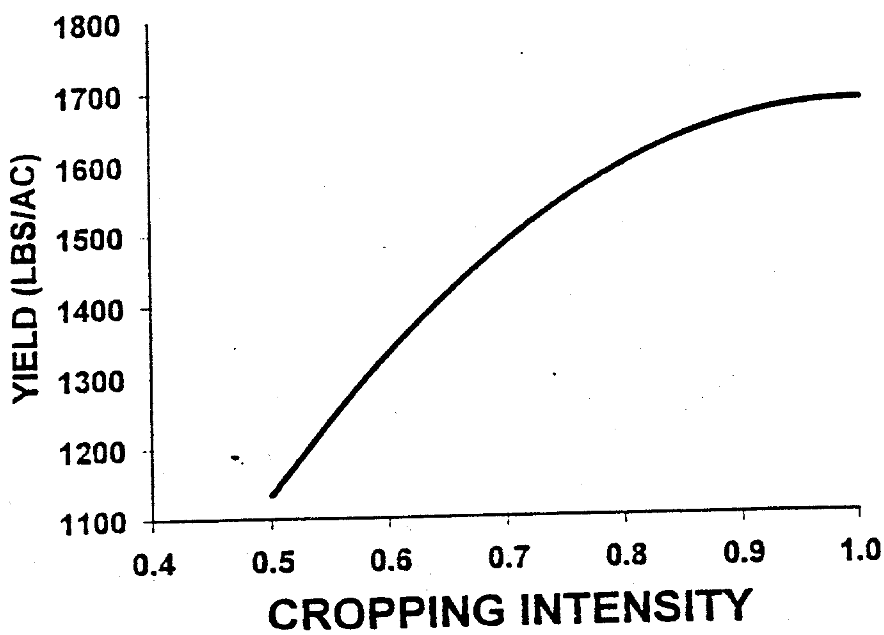
By diversifying crop rotations to control winter annual grasses, producers stimulate a synergistic cycle that improves several components of the soil system, thus leading not only to more efficient crop growth, but towards a healthier soil for future crops.

CAN WE DIVERSIFY?

Biological yield potential in northeastern Colorado:

This region can support more intensive cropping than winter wheat-fallow, especially if tillage is minimized. For example, a wheat-corn-fallow rotation's annualized grain yield was 70% greater than wheat-fallow at Sterling and Stratton (16). At Akron, grain yield on a Weld silt loam increases rapidly when crop intensity changes from 0.5 to 0.8. This suggests that this region has the biological potential to support cropping intensities much greater than 0.5 (Figure 2). The Akron data represents yield from seven rotations comprised of winter wheat, corn, proso millet, and sunflower combined at different levels of cropping intensity.

Figure 2. Grain yield as affected by cropping intensity at Akron CO. Yields are expressed on an annualized basis to include the fallow investment. As an example, the cropping intensity of wheat-fallow is 0.5, wheat-corn-fallow is 0.67, and continuous cropping is 1.0.



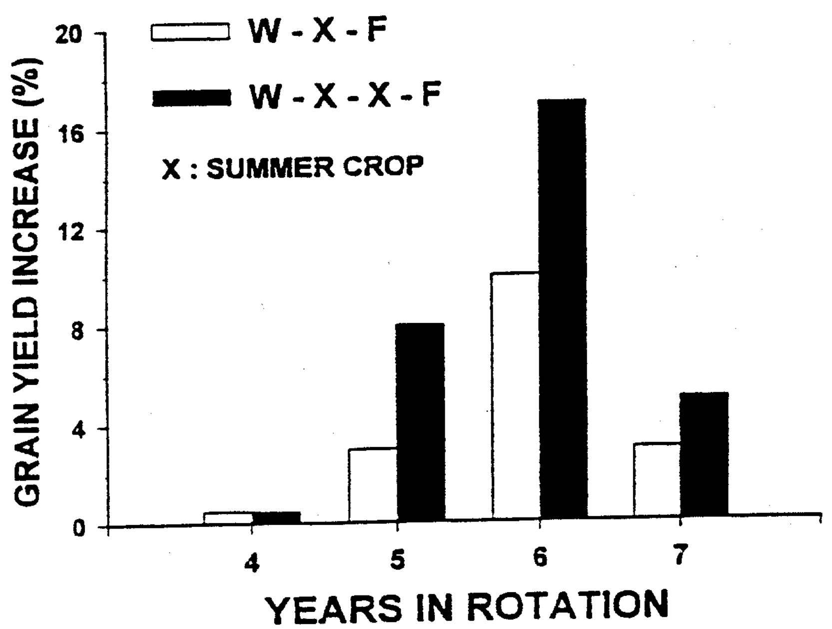
This increase in cropping intensity also is more profitable. The wheat-corn-fallow rotation yields 40% more gross return than wheat-fallow, while the wheat-corn-proso millet-fallow rotation is 25% more profitable than wheat-fallow (17).

A benefit of diversity - rotational effect on grain yields:

Crop yield can be favorably increased by crop sequencing. This response, termed the "rotational effect", is define as the beneficial effect on crop yield when rotating different crops in sequence (8, 22). An example is rotating corn with soybeans, which leads to corn yield increases of 10 to 20% per acre in the Corn Belt.

In northeastern Colorado, winter wheat yields also are increased by the rotational effect (Figure 3). This effect did not occur until the 5th year of the rotation. In the 6th year, wheat yield increased 16% when two summer annual crops followed the previous wheat crop, compared to grain yield of wheat-fallow. The growing season of 6th year was wetter than normal, leading to root diseases, which rotations with summer annual crops minimize (7). This rotational effect was not as large in the 7th year, when precipitation was below normal, thus reducing the incidence of root diseases. Yet, grain yield was still 5% higher when two summer annual crops were included in the rotation.

Figure 3. Winter wheat grain yield as affected by crop rotation, 1993 through 1996 at Akron, CO. Wheat yields in alternative rotations were compared to wheat yields from wheat-fallow within the same year.



Thus far, we have not identified the specific causes for this yield increase, but several factors are recognized as contributors: improvements in soil moisture, soil nutrients, soil structure, soil microorganisms, or growth promoting substances associated with crop residue (8, 21). Other factors include reduced populations or infestations of weeds, insects, and pathogens (8, 22).

Diversity opportunities in this region:

Presently, most producers grow grass crops, such as winter wheat, proso millet, and corn, for grain on dryland sites. The recent development of the sunflower market in this region supplies producers with more diversity in crop choice. For example, sunflower has a tap root system, which can penetrate to eight feet deep in the soil profile (Table 1). This contrasts with proso millet whose roots usually only penetrate two to three feet. In addition, sunflower is a broadleaf crop, therefore, producers can more easily rotate herbicides with different modes of action. This practice reduces the development of herbicide-resistant weeds (5).

Table 1. Diversity in growth patterns with currently grown crops in Northeastern Colorado.

Factor	Winter wheat	Corn	Proso millet	Sunflower
Rooting depth (ft)	5-6	5-6	2-4	6-8
Root type	Fibrous	Fibrous	Fibrous	Tap-root
Water use (in)	14-16	15-18	11-13	16-20
Planting date	Sep 10-25	May 1-8	June 1-10	May 25-June 10
Plant type	Grass	Grass	Grass	Broadleaf
Residue longevity	High	High	Low	Low

With the available crops and the biological cropping potential in this region, producers can intensify and diversify their crop rotations. By pursuing this strategy of diversity, producers can increase their production as well as avoid or minimize pest problems, such as jointed goatgrass (3) or plant pathogens (7).

Is Diversity Needed?

Economic concerns:

The 1996 farm bill, Federal Agriculture Improvement and Reform (FAIR) Act, eliminates government payments in seven years. Producers can now pursue market-oriented farming, as well as grow any crop on their land, thus crop diversity can be used as a management strategy. Without payments, producers also may need to intensify their cropping levels for economic stability.

Ecological concerns:

The agricommunity is recognizing that soil is a living entity, with its health being affected by management and land-use decisions. The practice of fallow, extensively used in this region, may be starving the soil, and subsequently, degrading its long-term health (9). Thus, any cropping pattern that minimizes fallow improves soil quality and long-term productivity (6).

Soils have an unique buffering capacity to adjust to changes, such as loss of organic matter. Therefore, cumulative deleterious effects may be, in the short term, masked by this buffering. However, if a threshold is exceeded, it is possible that irreversible damage may occur, such that the soil system is not able to recover (23).

Literature Cited

1. Aldrich, S.R., W.O. Scott, and E.R. Leng. 1978. Modern Corn Production. A & L Publications, Champaign IL. 378 pages.

2. Anonymous. 1995. Colorado Agricultural Statistics. Colorado Agric. Stat. Serv. Lakewood CO. 222 pages.

3. Anderson, R.L. 1994. Management strategies for winter annual grasses in winter wheat. p. 114-122, in Murphy, L.S. (ed.) Proceedings, National Intensive Wheat Management Conference. PPI and FAR, Denver, CO. 157 pages.

4. Bezdicek, D.F. and D. Granatstein. 1989. Crop rotation efficiencies and biological diversity in farming systems.

Am. J. Altern. Agric. 4:111-119.

5. Bird, G.W. 1994. Integrated pest management in a sustainable agriculture. p.34-41, in Proceedings, Second National Integrated Pest Management Symposium. Las Vegas, NV.

6. Bowman, R.A., R.L. Anderson, D.C. Nielsen, M.F. Vigil, and A.D. Halvorson. 1996. Effects of cropping intensity on soil organic matter and aggregate stability. p. 174-182, in J. Havlin (ed.) Proceedings, Great Plains Soil Fertility Conference. Denver, CO.

7. Cook, R.J. 1994. The place for IPM in the next decade. p.4-16, in Proceedings, Second National Integrated Pest Management Symposium. Las Vegas, NV.

8. Crookston, R.K., J.E. Kurle, P.J. Copeland, J.H. Ford, and W.E. Lueschen. 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J. 83:108-113.

9. Doran, J.W., M. Sarratonio, and M.A. Liebig. 1996. Soil health and sustainability. Am. Soc. Agron. Advances in Agronomy. Vol. 56:1-54.

10. Elliot, L.F. and J.M. Lynch. 1995. The international workshop on establishment of microbial inocula in soil. Am. J. Altern. Agric. 10:50-73.

11. Francis, C.A. 1989. Sustaining agriculture and development: challenges for the future. Am. J. Altern. Agric. 4:98-100.

12. Galvez, L., D.D. Douds, Jr., P. Wagoner, L.R. Longnecker, L.E. Drinkwater, and R.R. Janke. An overwintering cover crop increases inoculum of VAM fungi in agricultural soil. Am. J. Altern. Agric. 10:152-156.

13. Jawson, M.D., A.L. Franzluebbers, D.K. Galusha, and R.M. Aiken. 1993. Soil fumigation within monoculture and rotations: response of corn and mycorrhizae. Agron. J. 85:1174-1180.

14. Katan, J. 1995. Interactions of roots with soil-borne pathogens. p. 811-822, in Waisel, Y. and A. Eshel, (ed.) Plant Roots -- the Hidden Half. Marcel Dekker, Inc. New York.

15. Odum, E.P. 1971. Principles and concepts pertaining to

organization at the community level. p. 140-161 in Fundamentals of Ecology. W.B. Saunders Company, Philadelphia, PA.

16. Peterson, G.A., D.G. Westfall, and C.V. Cole. Agroecosystem approach to soil and crop management research. Soil Sci. Soc. Am. J. 57:1354-1360.

17. Peterson, G.A., D.G. Westfall, N.E. Toman, and R.L. Anderson. 1993. Sustainable dryland agroecosystem management. Colorado State Univ. Exp. Stn. Tech. Bull. TB93-6. 34 pages.

18. Power, J.F., J.W. Doran, P.T. Korner, and W.W. Wilhelm. 1994. Long-term residual effect of crop residues in eastern Nebraska. p. 143-150, in Proceedings, A Future Using Residue Management, Great Plains Agric. Council Bull. 150.

19. Sahs, W.W. and G. Leosing. 1985. Crop rotations and manure versus agricultural chemicals in dryland grain production. J. Soil & Water Conserv. 40:511-516.

20. Smolik, J.D., T.L. Dobbs, and D.H. Ricker. 1995. The relative sustainability of alternative, conventional, and reduced-till farming systems. Am. J. Altern. Agric. 10:25-35.

21. Voss, R.D. and W.D. Schrader. 1984. Rotation effects and legume sources of nitrogen for corn. p. 61-68. in D.F. Bezdicek et al. (ed.) Organic farming: current technology and its role in a sustainable agriculture. ASA Spec. Publ. 46, Am. Soc. Agron., Madison, WI.

22. Vyn, T.J., J.C. Sutton, and B.A. Raimbault. 1991. Crop sequence and tillage effect on winter wheat development and yield. Can. J. Plant Sci. 71:669-676.

23. Warkentin, B.P. 1995. The changing concept of soil quality. J. Soil & Water Conserv. 50:226-228.

24. Wilhelm, W.W., L.N. Mielke, and C.R. Fenster. 1982. Root development of winter wheat as related to tillage practice in western Nebraska. Agron. J. 74:85-88.